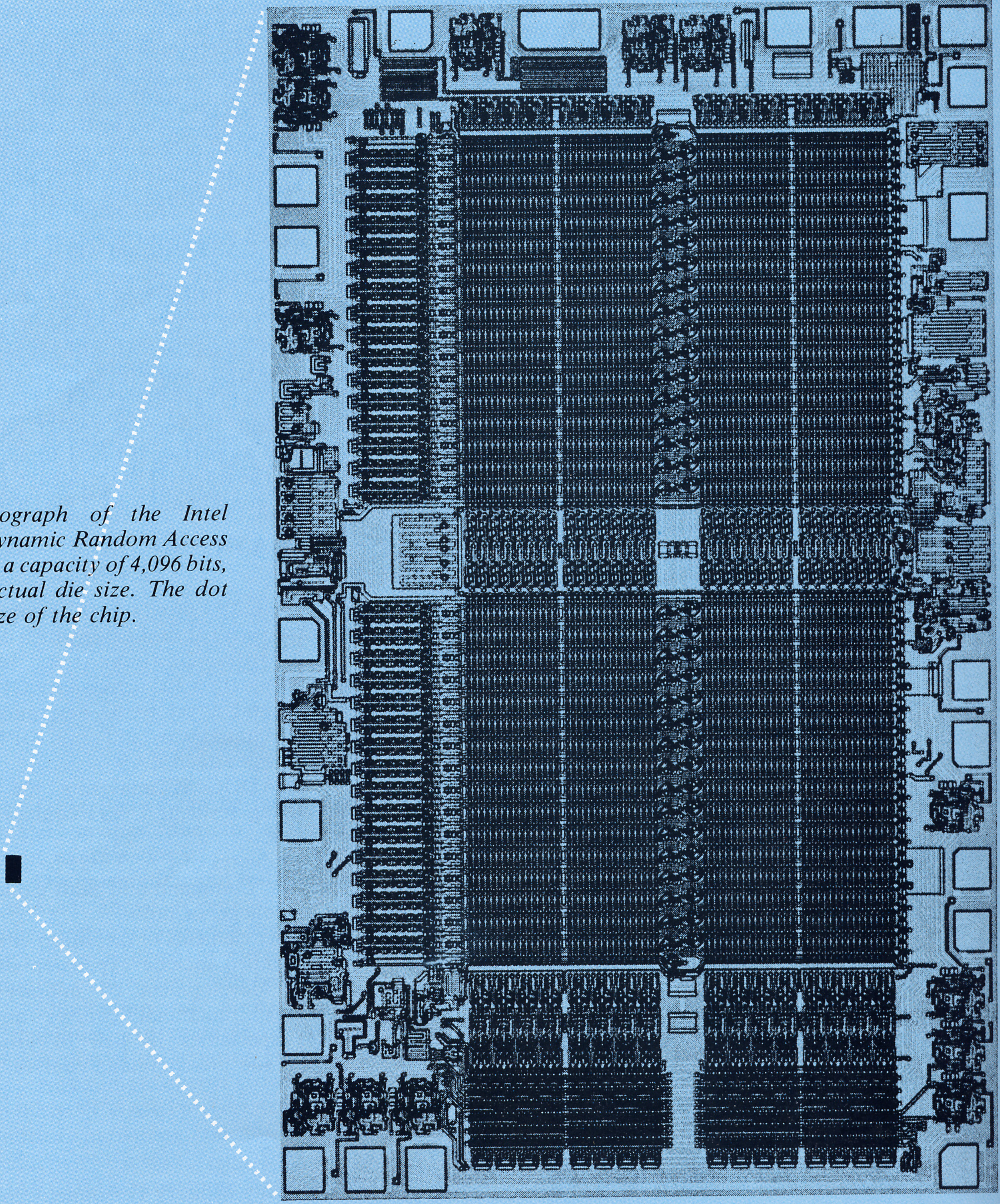
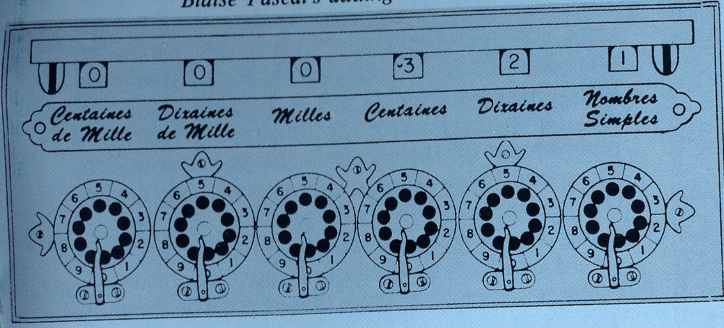
EVOLUTION OF THE COMPUTER

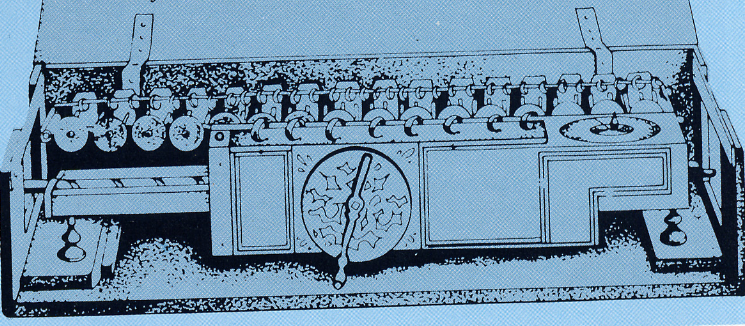
This photomicrograph of the Intel 2107B, which has a Dynamic Random Access Memory (RAM) with a capacity of 4,096 bits, is shown 40 times actual die size. The dot below is the actual size of the chip.



Blaise Pascal's adding machine, 1642



Gottfried von Liebniz's stepping calculator, 1672



by 1st Lt. Peter M. Murphy

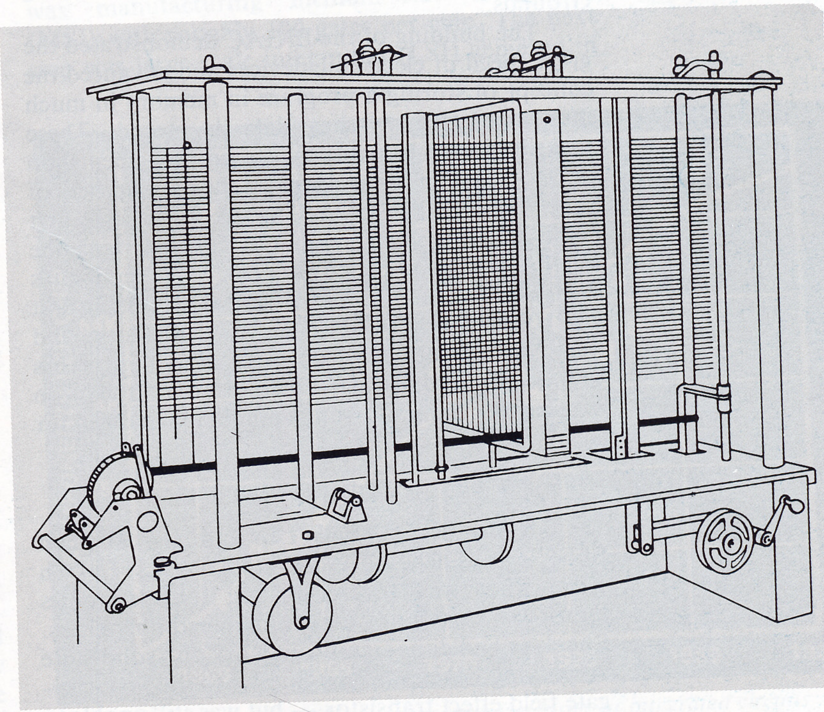
By the time this article appears in print it will be out of date. That may give the reader some indication of the pace at which computer technology is advancing today. Imagine that somewhere today an engineer is dreaming up a new digital electronic device. That dream still needs to be developed, designed, prototyped, produced and marketed. All of this will take about one year. During that year, breakthroughs in technology will have made that device obsolete before it ever reaches the consumer. Industry simply cannot keep up with scientific developments.

Credit for invention of the first computer has been contested in both the scientific community and the courts. How the issue is decided depends much on how a computer is defined. The oldest digital computing device known to man is the human hand. However, we are more properly concerned with the machine version of the human gray matter. In 1642, Blaise Pascal invented the mechanical adding machine which used a series of wheels and levers to perform addition and subtraction. Baron Gottfried von Leibnitz improved upon Pascal's machine in 1671 thus producing the first mechanical calculator which could also multiply and divide.

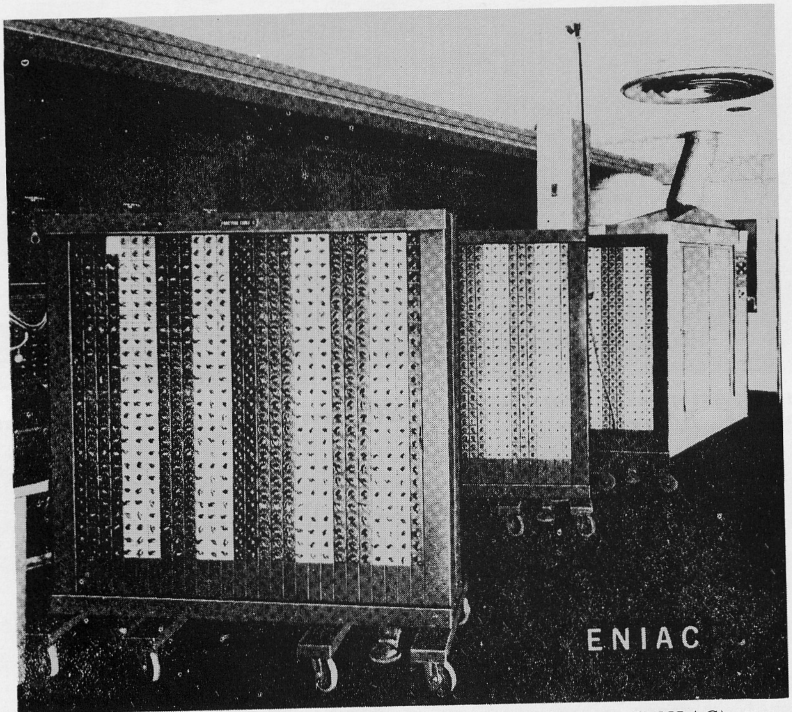
Perhaps the father of the modern day computer was Charles Babbage, an English mathematician. Babbage was frustrated with the process of having teams of mathematicians grinding away on seemingly endless equations to produce mathematical tables. He was convinced there had to be a better way. In 1830, he conceived the plans for a mechanical computer which could automatically print the results of these calculations. With a grant from the British government, Babbage worked on his computer until his death in 1871. His device was never realized because the requisite precision parts could not be manufactured with the technology of his age.

The first automatic, electronic, digital computer was constructed in the basement hallway of the Physics Building on the Iowa State University campus. The inventors were John Atanasoff, Professor of Mathematics and Physics, and Clifford Berry, Physics graduate student.[1] Operational in 1939, the Atanasoff-Berry Computer (ABC Computer) was a special purpose machine designed to solve large systems of simultaneous linear algebraic equations. It contained 300 vacuum tubes and employed a memory consisting of a drum with 1632 capacitors mounted on it. Early technology made these components fairly unreliable and the failure rate was so high that, statistically, the machine could never be successfully turned on. To solve this problem, each component was aged by applying power to it individually before installing it in the computer. Those elements with a short life were identified and discarded. In this way the ABC Computer became a reality. It sometimes worked for a whole week between breakdowns.

Between 1939 and 1945, the Ordnance Department of the United States Army sponsored the development of the ENIAC at the University of Pennsylvania. The ENIAC development team was led by J. Presper Eckert and John W. Mauchly; the



In the 1830's Charles Babbage designed and built a working model of his "difference engine" — a steam driven assembly of gears that could compute and print tables automatically.



The Electronic Numerical Integrator and Calculator (ENIAC) was built between 1942 and 1946 at the University of Pennsylvania. It was the first to use electronic tubes for calculating.

mathematical consultant to the group was John von Neumann, one of the greatest contributors to the evolution of the computer. ENIAC was the first computer operating from an internally stored program containing some 18,000 vacuum tubes. It was used to simplify the calculations of the trajectory firing tables at Aberdeen Proving Grounds.

The building of the ENIAC demonstrated the great speed of electronic devices and advanced the concept of storing a program in memory in much the same manner that data is stored. These contributions, together with improvements in electronics technology, inspired the development of a new system: the EDVAC. The ideas were first published by von Neumann in 1945 and the EDVAC was completed in 1950. Von Neumann's design was a machine with a central processing unit (CPU), main memory, auxilary memory and separate input and output devices. This architecture, sometimes referred to as the "von Neumann machine," would remain unchanged for nearly 30 years.

Transistor Age

Meanwhile, at Bell Laboratories, William Shockley was heading a solid-state physics research group that was revolutionizing the electronics industry with its study of semi-conductor materials. Shockley had done significant work on a solid-state amplifying device — now known as the Schottky-gate field effect transistor — but was still unable to produce a satisfactory prototype. Two members of the group, John Bardeen and Walter Brattain shared the Nobel Prize in physics with Shockley for the invention of the bipolar junction transistor in December 1947. At the time, Bardeen and Brattain were studying the field effect transistor in an attempt to improve it when unexpected current in their probe led them to this accidental discovery.

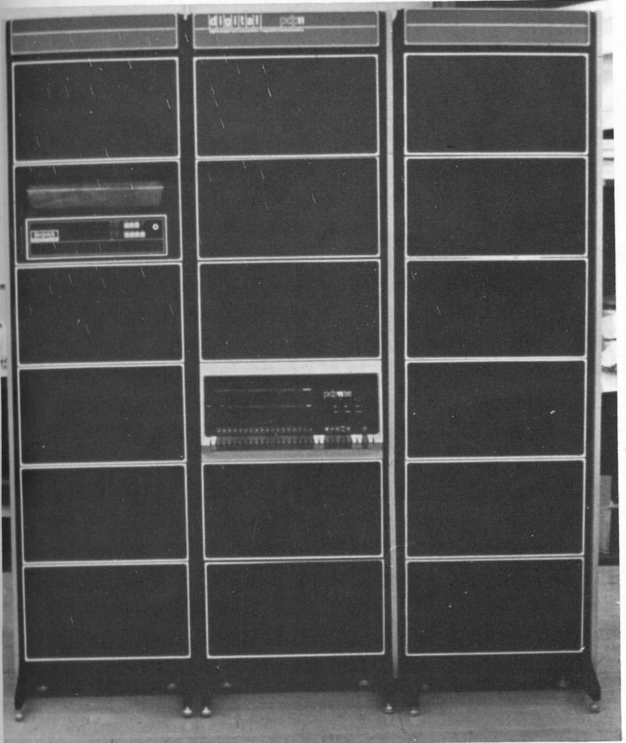
The acceptance of the transistor as a general replacement for the vacuum tube was slow at first. The second generation computers were born when this electronics wonder was fully utilized. Computers no longer filled entire hallways but would comfortably fit into a single room. Power consumption and size decreased while computing time was reduced to microseconds. Reliable computer technology was obtained for the first time and thus the computer was elevated from the world of academic novelty to a dependable tool.

Transistors the size of an eraser on a pencil were more difficult to mount and replace than were the large vacuum tubes. In the early 1950s progress on this interconnection problem was made with the development of printed circuits by S. F. Danko of the Signal Corps. Though surely an improvement over vacuum tubes, a better solution had to be found. In a 1952 address to the Electronic Components Conference, G. W. A. Dummer of the Royal Radar Establishment in England predicted

Inter Tube II Computer terminals used by the Officer's Department at Fort Gordon, GA, employ a microprocessor in each unit to make it a "smart" device.

"electronics equipment in a solid block with no connecting wire." Possibly inspired by this statement, the U.S. Air Force pursued what was termed "molecular electronics" during the mid-1950's. After several discussions, a contract was awarded to Westinghouse in 1959 to systematically invent such devices.

The Army was also interested in microminiaturization or the "Micro-Module" as they called it. This was an outgrowth of the

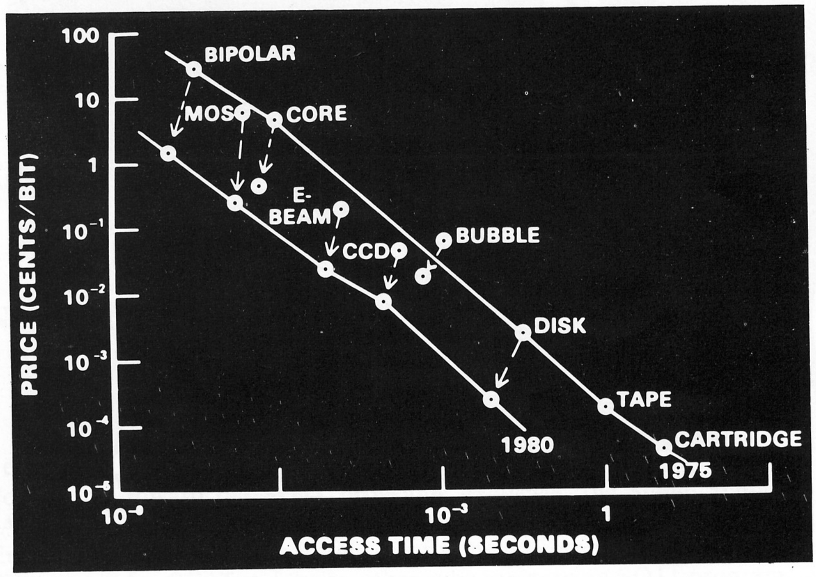


The PDP 11/35 minicomputer, manufactured by Digital Equipment Corporation (DEC), is a third generation computer slightly taller than the average man.

National Bureau of Standards assembly technique as developed by the Signal Corps. Texas Instruments received the Army contract in 1958 to work on the Micro-Module approach. Jack Kilby, a recently hired engineer, was assigned to this ambiguously defined project, and it was his insight that led to the first solid-state circuit. Now several transistors could be integrated onto a piece of silicon (chip) only a few millimeters square.

The silicon integrated circuit (IC) was not hailed as the landmark of a new era. It had many critics and was seen as having only very specialized applications. The first support came from the Air Force because of a small group with enough foresight to recognize that this new concept provided a systematic design approach and would eliminate the need to invent thousands of new devices which would be required in future equipment.

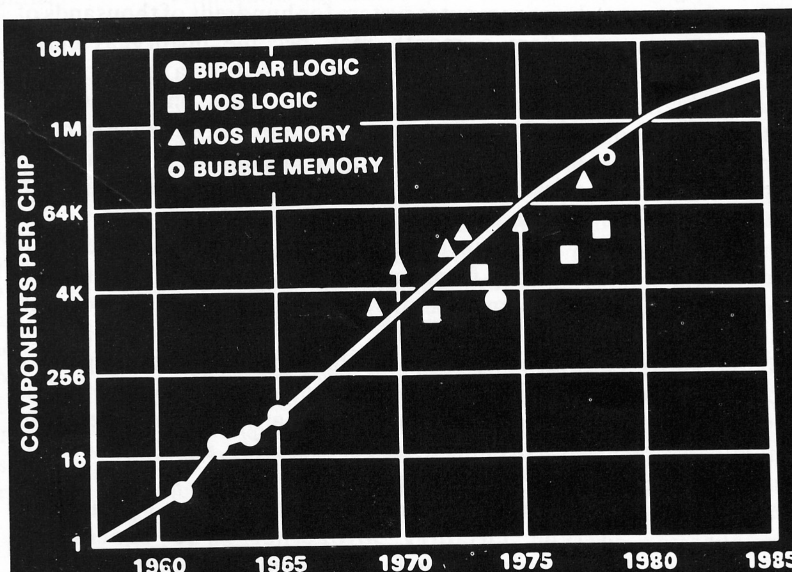
The integrated circuit meant another decrease in power consumption and an increase in computing speed. Calculations were now measured



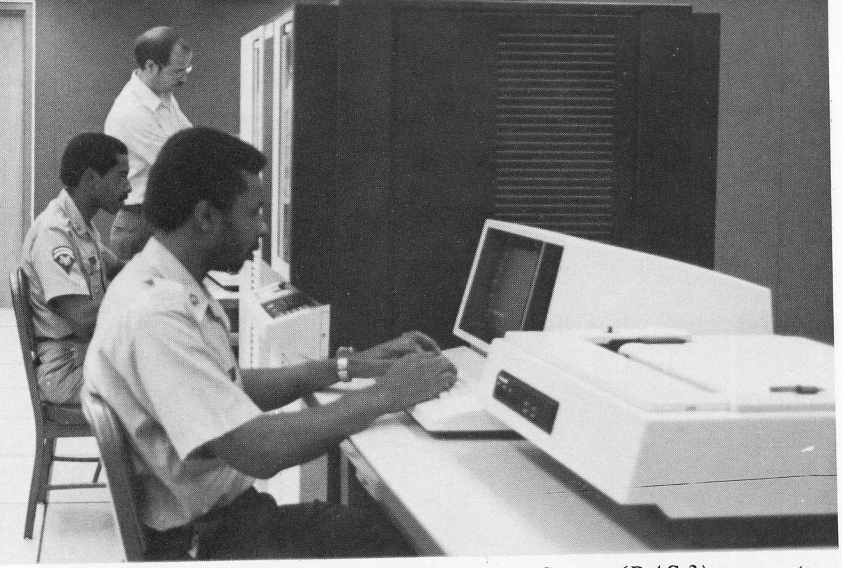
All computer memory technologies have gotten faster and cheaper thanks to technology advances.

in nanoseconds and the room sized computer made way for the third generation which sits quietly against one wall of that same room.

In 1960, Texas Instruments announced the first integrated circuit for commercial sale. IC's manufactured in 1964 were classified as small-scale integration (SSI) having fewer than a dozen transistors on a chip. Without any significant increase in size, the circuit density (amount of circuitry that can be squeezed into a set area) increased an order of magnitude (a factor of ten) in four years. Thus in 1968 the electronics industry was manufacturing medium-scale integration (MSI) with roughly 100 gates per chip. The next step was large-scale integration (LSI) achieved in



Over the last two decades, the circuit density of integrated circuits has doubled every 18 months. This trend is expected to continue for another decade at least.



The Decentralized Automated Service Support System (DAS-3) represents the state-of-the-art technology in minicomputer systems to be used for tactical logistical support.

1970. LSI circuits, like the first microprocessor developed by Intel, contained over 1000 gates. The most recent jump was to very-large-scale integration (VLSI) yielding over 200,000 gates on a single surface just 3 millimeters on edge. This will significantly reduce the size and power consumption of the fourth generation computer which will be small enough to be set on a table top.

Pipe dreaming

Over the last 15 years, circuit density of IC's has doubled almost every year taking the world from SSI to VLSI. With the technology presently in the pipeline, this trend will continue for at least another decade.[5] Computer engineers are proposing to use VLSI to design serious alternatives to the von Neumann machine.[6] Distributed processing and network organizations are just two of the new vistas to explore. The day of renting a large computer system for hundreds of thousands of dollars a month may become history as entire systems can now be purchased for a few thousand dollars. A microprocessor costs only about $10 which surely makes it economically feasible to buy a new computer any time another task requirement arises, instead of finding a way for one centralized system to handle a larger workload.

The increase in circuit density has come about not only from making the gates on an IC smaller, but from quantum leaps in technology. New or even radical methods have been responsible for overnight jumps in the process of crowding more transistors on a piece of silicon. Some of these methods have been to depart from the widespread use of silicon as the base for an IC. The most recently marketed advancement is the bubble memory which deviates from the use of transistor type circuitry altogether. The process of manufacturing bubble memories is less likely to introduce flaws in the circuit. This allows the engineer to design larger circuits than before. A typical bubble memory may be equivalent to a traditional IC with several million gates.

Another significant achievement was made 18 years ago by Brian Josephson, a British graduate student, who performed work on superconducting circuits (a circuit cooled to less than -260°C). His discovery, the "Josephson Junction," may replace the use of transistors on IC's in computers of the future the way transistors replaced the vacuum tube.[7] A Josephson computer may be on the market by the end of the decade and will be 20 times faster than today's best. Though it will be no larger than a telephone it will have the computing power of IBM's top-of-the-line.

The Army was once responsible, both directly and indirectly, for the rapid beginnings of the computer age. Today the military has been left behind as if they had fallen from an accelerating train. It may be difficult to get back on board but efforts have begun with hopes to lead industry again. The Department of Defense began a six-year project in 1979 which it has named Very-High-Speed Integrated Circuits (VHSIC).[8] The project will work to systematically advance the technology of VLSI for military applications. 1986 has been designated its target date for pilot production of microprocessors with 250,000 gates and an operational clock speed of 25 MHz. The first Teleprocessing Operations Officers Course (SSI 25B) began at Fort Gordon, GA, in October 1980. With the addition of SSI 25B, the Army hopes to maintain a pool of current professional expertise in computer engineering.

Most of the computer age has taken place in the last 30 years, and the pace is just beginning to pick up. The computer will become a part of everyday life whether it be on the battlefield, at work, in school or at recreation.

Endnotes

1. Sperry Rand v. Honeywell, U.S. District Court Minnesota, October 1973.

2. Jack Kilby, "Invention of the Integrated Circuit," *IEEE Transaction of Electron Devices,* July 1976.

3. William Shockley, "The Path to the Conception of the Junction Transistor," *IEEE Transaction on Electron Devices,* July 1965.

4. Arthur Glaser and Gerald Subak-Sharpe, *Integrated Circuit Engineering,* 1977.

5. Gordon Moore, "Progress in Digital Integrated Electronics," IEEE International Electron Devices Meeting Talk 13, Washington, D.C., December 1975.

6. Robert Bernhard, "Computers: Emphasis on Software," *IEEE Spectrum,* January 1980.

7. Wilhelm Anacker, "Computing at 4 Degrees Kelvin," *IEEE Spectrum, May 1979.*

8. Ruth Davis, "The DoD Initiative in Integrated Circuits," *Computer,* July 1979.

9. Tito Lebano, "SS1 25B: A New Teleprocessing Operations Course for Officers," *THE ARMY COMMUNICATOR,* Spring 1980.

Lt. Murphy holds an ROTC commission from Iowa State University where he also earned a B.S. in electrical engineering and another in computer engineering. Before entering the military, Murphy was involved with computer security experiments at NSA.